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BANGEX 5 Preliminary Report

by

Peter S. Guest
Andreas K. Goroch
David G. Bieger
Richard J. Lind
Kenneth L. Davidson

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NAVAL POSTGRADUATE SCHOOL
Monterey, California 93943-5000

Daniel Oliver
President

Leonard Ferrari
Executive Vice President and
Provost

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Peter S. Guest
Associate Research
Professor of Meteorology
Naval Postgraduate School

Andreas K. Goroch
Meteorologist
Naval Research Laboratory- Monterey

David G. Beiger
Captain, USAF
Naval Postgraduate School

Richard J. Lind
Meteorologist
Naval Postgraduate School

Kenneth L. Davidson
Professor of Meteorology

Reviewed by:

Philip A. Durkee
Chairman
Department of Meteorology
Naval Postgraduate School

Released by:

Dan C. Boger
Interim Associate Provost
and Dean of Research
Naval Postgraduate School

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13. ABSTRACT

This report describes preliminary results from the BANGEX 5 field exercise which occurred at the China Lake Test Range JCIF facility 3 – 5 June, 2008. The goal of this research is to improve our forces ability to detect improvised explosive devices (IEDs) from aircraft. Considerable progress has been made toward this goal as a result of this exercise.

A variety of surface environmental measurements were performed to characterize the conditions associated with IEDs and the accompanying changes to the local soil conditions. These were complimented by operational aircraft imaging measurements (movies) of various simulated IED and non-IED targets. These measurements will be used to improve the physics used in IED detection numerical models. Although analysis of these data are just beginning, the authors and collaborators have already verified that IED locations can be detected from high-flying aircraft sensors by the thermal and visible signatures of disturbed soil and other changes in the local environment. The measurements described here will form the basis of the follow-up studies that will be presented in future reports and in the thesis of Capt. Bieger.

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EXECUTIVE SUMMARY

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I. INTRODUCTION

This report represents the first look at results from the Buckley Air National Guard Exercise 5 (BANGEX 5) which occurred 3-5 June, 2008. Contrary to the name (a leftover from earlier exercises) the exercise was performed at the China Lake Test Range in California, operated by the Naval Air Warfare Center Weapons Division (NAWCWD). This report is preliminary and is intended to provide background information and a quick look at some of the measurements and results. The authors are just beginning to process the data collected, a final report and student thesis will be provided at later date. After this introduction this report will provide background information, a description of the experiment, some preliminary results and conclusions.

II. BACKGROUND

Improvised Explosive Devices (IEDs) continue to be an all-purpose weapon of enemy combatants in both Iraq and Afghanistan. These weapons are often victim triggered and are designed to kill, maim or otherwise incapacitate friendly and coalition forces. IEDs may come in many forms, but the most typical are buried explosives (e.g. mines or shells) either remotely detonated or victim triggered.

The use of aircraft-borne sensors to detect IEDs is currently being utilized in the field with a degree of success, but more can be done to further exploit this capability. The goal of our research is to improve our ability to detect IEDs with aircraft.

An important tactical aid used for detecting targets (including IEDs) is the Target Acquisition Weapons Software (TAWS). TAWS is a sophisticated software package that was developed by the Air Force Research Laboratory, the Navy SPAWAR Systems Center, the Navy Research Laboratory, the Army Research Laboratory, the Army Topographic Engineering Center, the Air Force Weather Agency and the Coast Guard R&D Center. TAWS uses a variety of environmental, sensor, target and mission parameters to produce several products including detection range as a function of approach angle and times of thermal crossover. The TAWS input parameters can be based on real time measurements or predictions so the model can be used for mission planning days in advance (based on forecasts) or just before or during missions using real time information. An ultimate goal of this research is to develop target models for IEDs that can be used in the TAWS program to predict the best and worst times of day and approach angles for detection of IEDs using various sensors.

The key collaborator for this exercise was Dr. Andreas Goroch of the Naval Research Laboratory (NRL) in Monterey, CA. Dr. Goroch is the lead scientist and primary designer of the BANGEX exercises. Prior to BANGEX 5 there were several Naval Postgraduate School (NPS) students involved in similar research. For BANGEX 4, Capt. Andrew Frey, USAF, and Richard Lind from the NPS Meteorology Dept., in collaboration with Dr Goroch, deployed a variety of meteorological and soil sensors to quantify how the various target and background temperatures changed during the measurement period. Capt. Frey analyzed these data for his MS Thesis. Capt. Frey compared the environmental measurements with the TAWS predictions and the images obtained by the aircraft. Despite the attempts to disguise the thermal signatures of the simulated IEDs, they were detectable by the aircraft, indicating that this detection can be modeled in a quantitative way.

An earlier NPS student, Capt Tiffany Bendorf, USAF, advised by Drs. Davidson and Goroch, did her thesis research on a similar experiment (with some different imaging sensors), BANGEX 3, that occurred in November, 2006 and she also focused on IED detection. Our current efforts are built in part on these earlier research efforts.

III. EXPERIMENT DESCRIPTION

A. Section Introduction

BANGEX-5 was the latest in a series of exercises conducted at China Lake NWC, CA. This exercise was conducted in a similar fashion as the previous four in that a series of flights were made over simulated IED targets both on the surface and buried beneath it. Previous exercises used multiple sensors on board multiple aircraft, but this exercise focused specifically on the capability of one sensor pod type. A USAF F-16 and a USMC AV-8B configured with visible and infrared (IR) targeting pods overflew the target set during the mid-morning hours and later in the day around sunset. Several low and medium altitude passes were made from multiple approach angles to compare the impact of atmospheric effects on detection probability and range.

Quantitative measurements were performed using surfaced based meteorological sensors collecting data on the basic parameters (wind, temperature, humidity). In addition, temperature profile data was collected in the sub soil from the surface to 20 cm and above the surface to about a half meter. This will provide a two dimensional plot of temperature in time during each of the over flights. Direct measurements of the surface fluxes of heat, moisture and momentum were also obtained at two levels. Soil moisture data was also collected along with surface based IR measurements of the ground and an exposed target. Ultimately, this will provide a controlled data input from which further analysis will be made.

Qualitatively, imagery from the targeting pods was paired with detailed dialogue from the aircraft pilots to develop a sight picture in time of the surface and buried IED targets. Detailed information is provided regarding the sensor altitude and range and the time of observation, but the human element will provide an operators perspective into how this data is interpreted. This provides the real world standard by which TAWS analysis will be measured and assessed.

It should be noted that the pilots involved in the exercise knew the location of the simulated IEDs. Experience from previous exercises demonstrated that there was not enough time or resources to have the pilots attempt to search and locate possible IED deployments. Although this may not represent a completely realistic scenario, it allowed maximum sensor time over the targets. This was determined to be the most effective use of the valuable aircraft assets. By maximizing the amount of images from different angles and times of the day, the authors and collaborators will best be able to analyze detection capabilities and develop improvements to the TAWS model.

B. Environmental Measurements

The first three authors deployed an environmental measurement system, designed by one of us (Lind), along a simulated concrete road at the Joint C4ISR Integration Facility (JCIF) within the China Lake NAWS test range (Figure1). The measurement system consisted of a tower with instruments to measure basic meteorological parameters near the surface (wind speed, wind direction, air temperature, air relative humidity and air pressure), direct measurements of surface fluxes (momentum, heat, moisture) at a two levels, 1 and 2 meters above the ground and a four level temperature profile in the lowest 1 meter of the atmosphere (Figure 2).

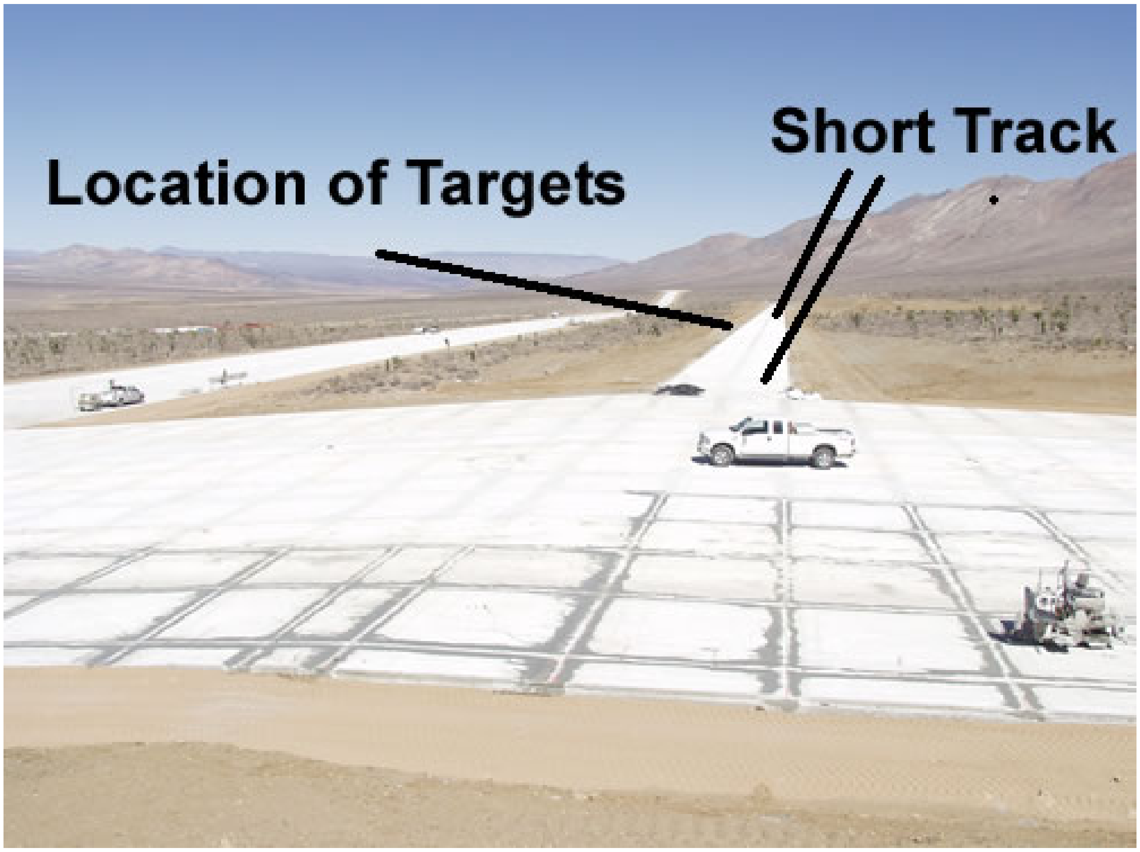

Figure 1. The JCIF test track showing location of the IED targets
on the short track before deployment.

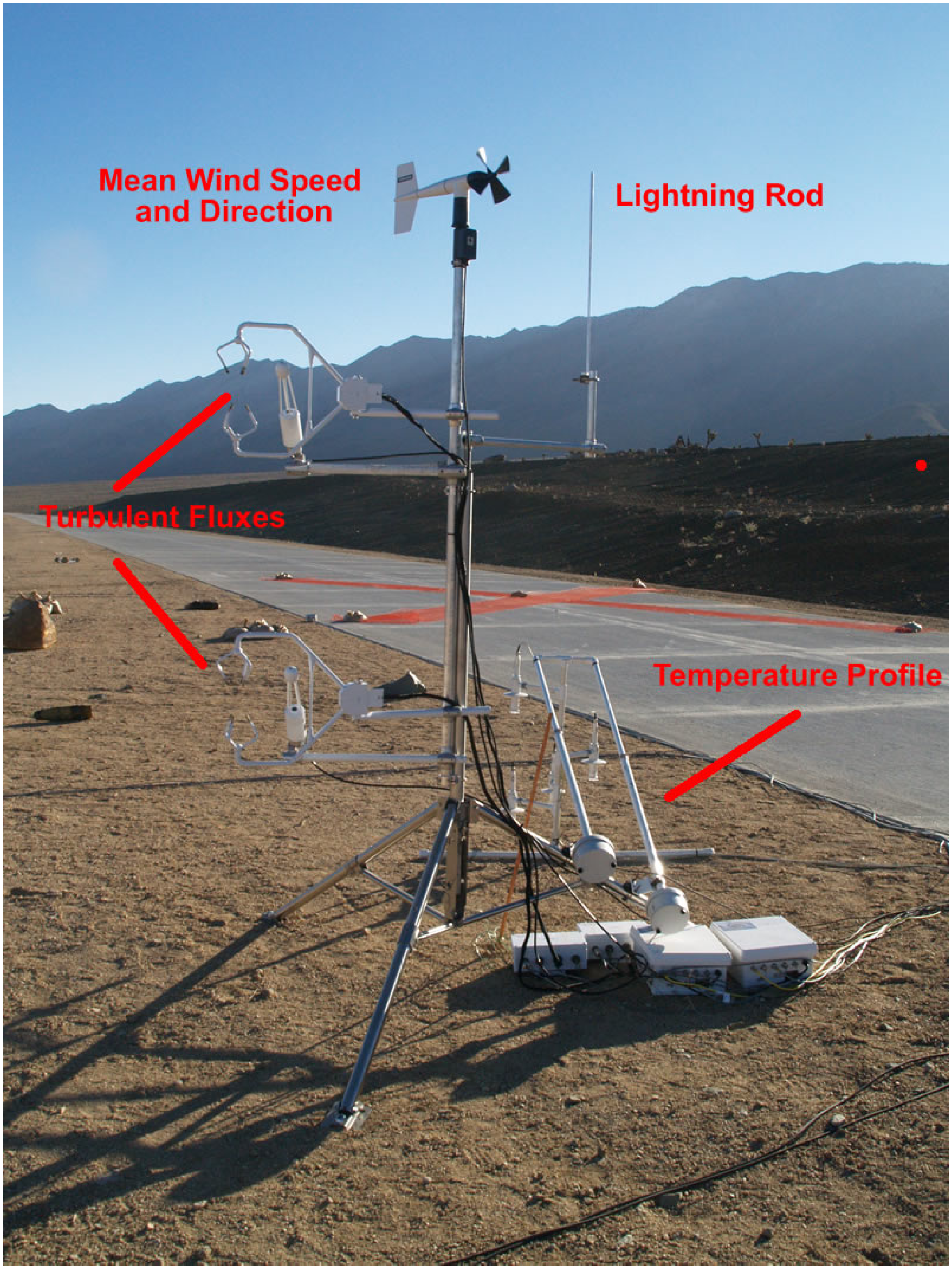

Figure 2. NPS meteorology tower showing location of various measurements.

A crucial aspect of target detection for IR sensors is the contrast between the target background temperatures. To quantify this an IR surface temperature sensing probe was aimed at one of the targets and another at the adjacent ground to determine target and background temperatures (Figure 3).

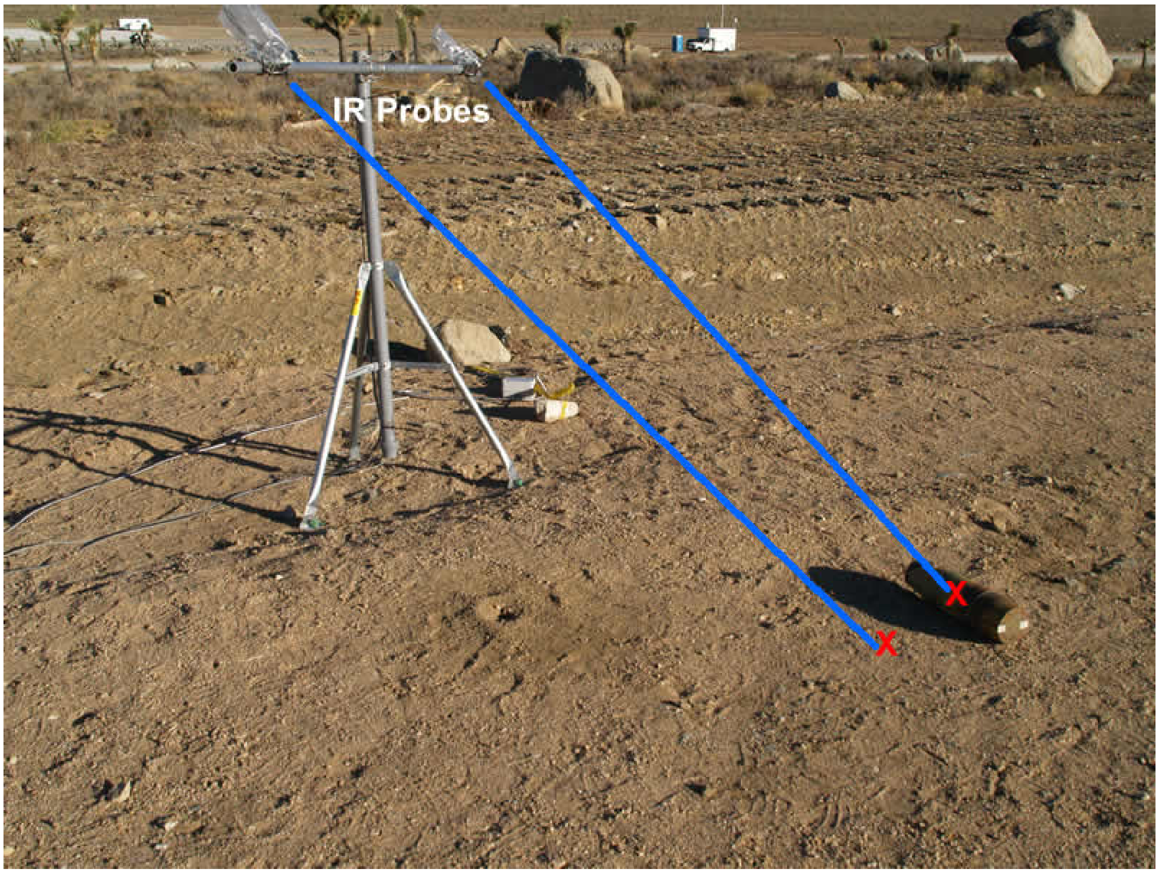

Figure 3. Two IR surface temperature measurement probes showing line-of-sight paths from each sensor (blue lines) and location of surface temperature measurement (red crosses). The right probe is pointed toward a simulated IED on the surface and the left probe is pointed toward the adjacent ground.

In addition to these measurements, the NPS participants deployed several thermistors (small thermometers) on the targets and at various levels within the soil to quantify the temperatures and soil transmission of heat (not shown).

C. Targets

Prior to the experiment, personnel at the JCIF facility constructed several simulated IEDs. The primary IED simulator was a 120 mm shell which has mass, size and heat conduction properties similar to a real IED. These shells were placed (10 directly on the ground (2) disguised by burlap and plastic bags, (3) within a simulated "rock", and (4) buried 30 cm below the surface. The simulated IEDs had wires attached to them connecting to simulated trigger devices about 5 meters away in the opposite direction from the track. In addition, bags and disturbed soil areas without the simulated IEDs were deployed or created for comparison (Figures 4 and 5).

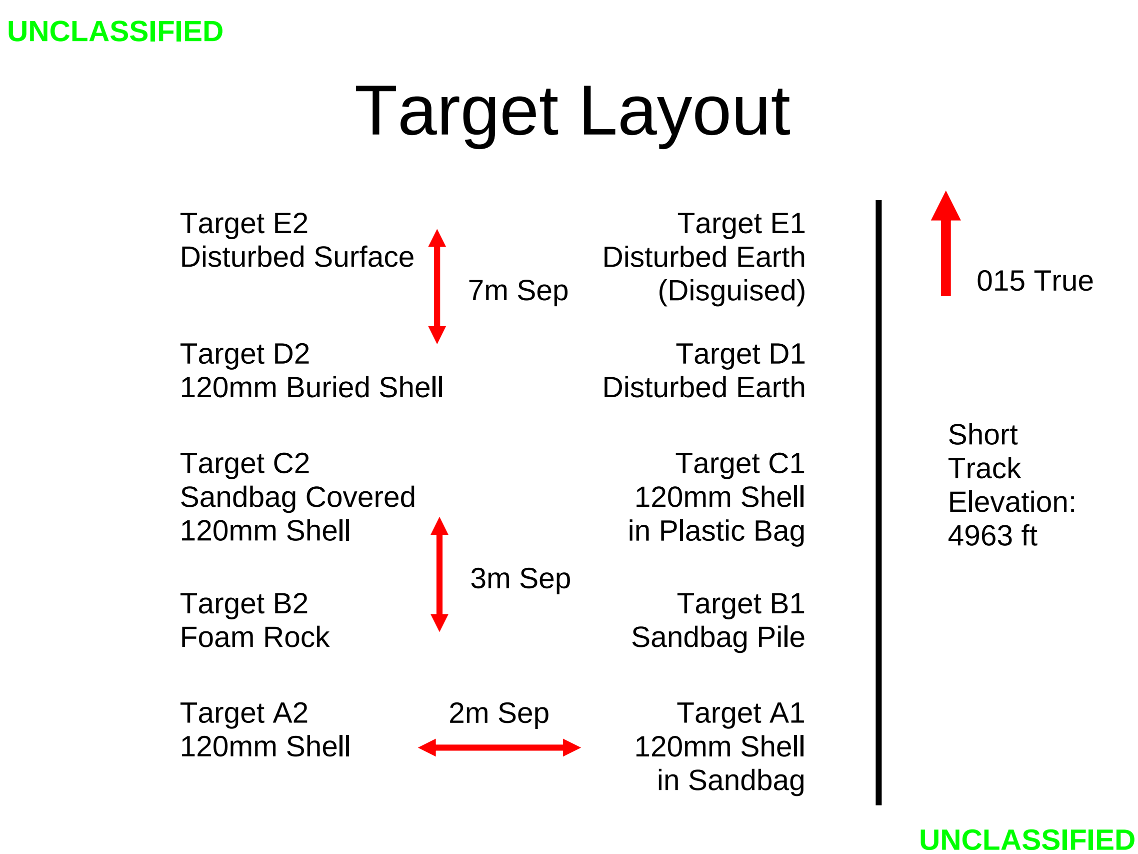

Figure 4. Schematic of target locations.

Figure 5. Photograph of targets in same orientation as the Figure 4 schematic. The triggering devices are in the ditch to the left and are almost impossible to detect on this photograph, as are the connecting wires. The red material on the runway forms a cross to aid the pilots in identifying the target location area.

D. Aircraft Measurements

Pilots aboard a USAF F-16 and a USMC AV-8B performed a total of 9 flights over the targets (counting each aircraft flight separately) during the exercise. Capt. Bieger briefed the pilots before each flight and a debrief was performed with the pilots and scientists after most flight missions. Missions were performed in the mornings and evenings for all three days 3-5 June, 2008 with the exception of the 4 June morning flights that were scrubbed due to high winds.

The basic flight paths consisted of "Shamrock" and "Orbit" patterns (Figure 6). Each pattern was flown several times during each flight at various altitudes.

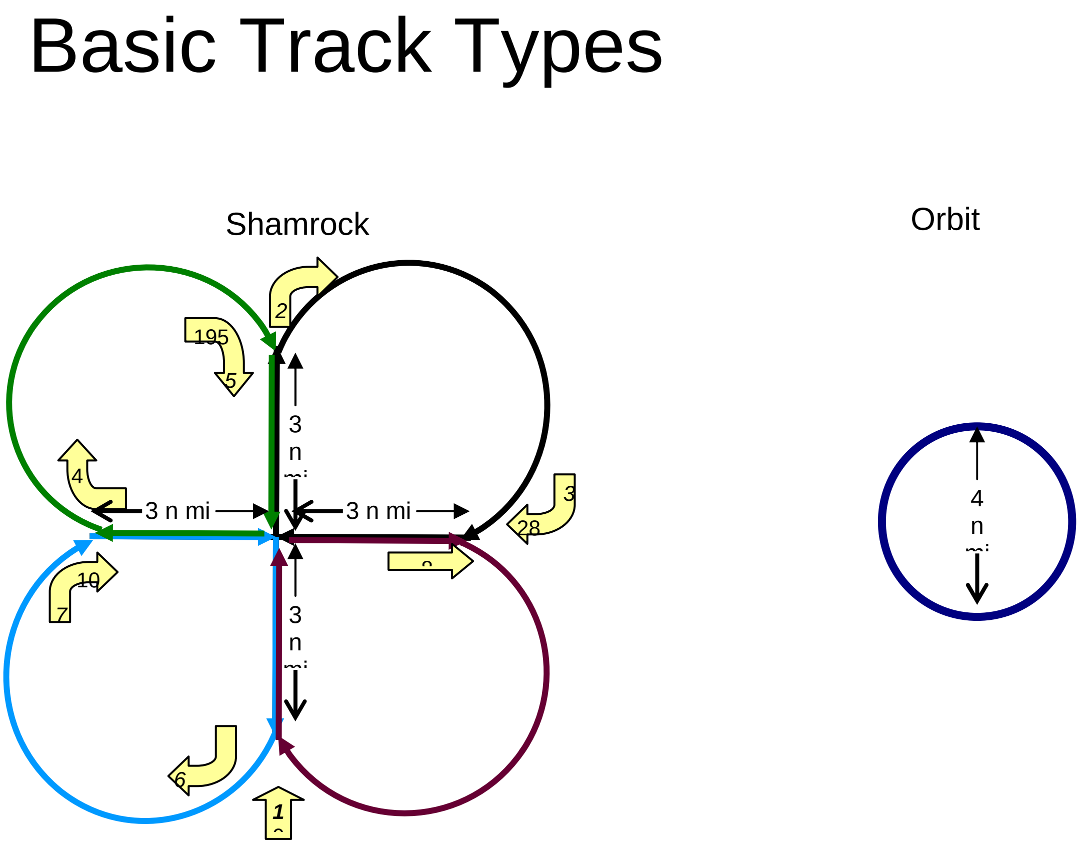

Figure 6. Aircraft flight patterns. Targets were located in the center of each track type diagram.

Each aircraft was equipped with similar operational visible and IR imaging sensors that created black and white movies of the target area for each flight.

IV. RESULTS

A. Environmental Measurements

The near surface atmospheric, direct surface (including target temperatures) and sub-surface soil measurements recording data every second for the time period starting in the afternoon of 2 June to the morning of 6 June, 2008 local time (PDT). The data collection was 100% successful, all parameter values were successfully recorded throughout the period and are available for analysis. The analysis of these data are just beginning, only cursory looks have been performed to check for proper data collection and accuracy. The values appear to be realistic and representative of actual conditions. It is possible one or two of the thermistors slipped and may not be representative of what was trying to be measured, but this was a minor problem that will have no significant affect on the quality of the data analysis since these measurements were duplicated by other thermistors. An accuracy analysis of the data will be performed in the near future.

Figures 7 – 12 show time series of some of the environmental data parameters. These figures were created from Excel and are intended to show the basic nature of the data. A more detailed and in-depth analysis and graphics production will be performed over the next few months.

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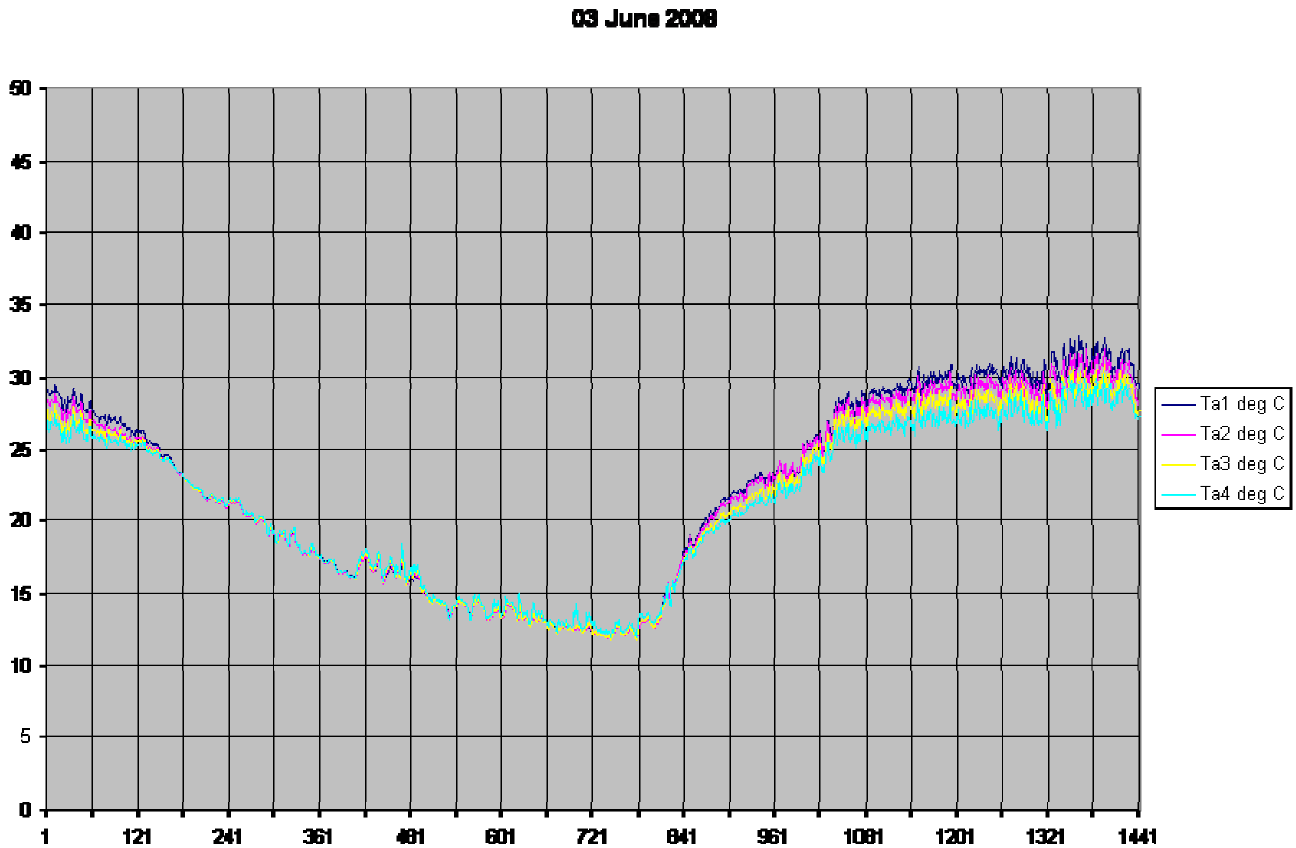

Figure 7. Time series of temperature profile data for 03 June (UT). The vertical axis represents temperature (◦C) while the bottom axis represents number of minutes from the start of the day in UT time. The leftmost part of the figure represents 1700 local (PDT) time on 2 June, 2008 while the rightmost part represents 1700 (PDT) time on 3 June, 2008. The four lines represent the temperature at various levels above the ground with lower numbers representing lower elevations. Note the diurnal temperature cycle associated with solar radiation. At night (minutes 120 – 800) the temperatures were nearly the same at all levels while in the daytime the lower temperatures are greater.

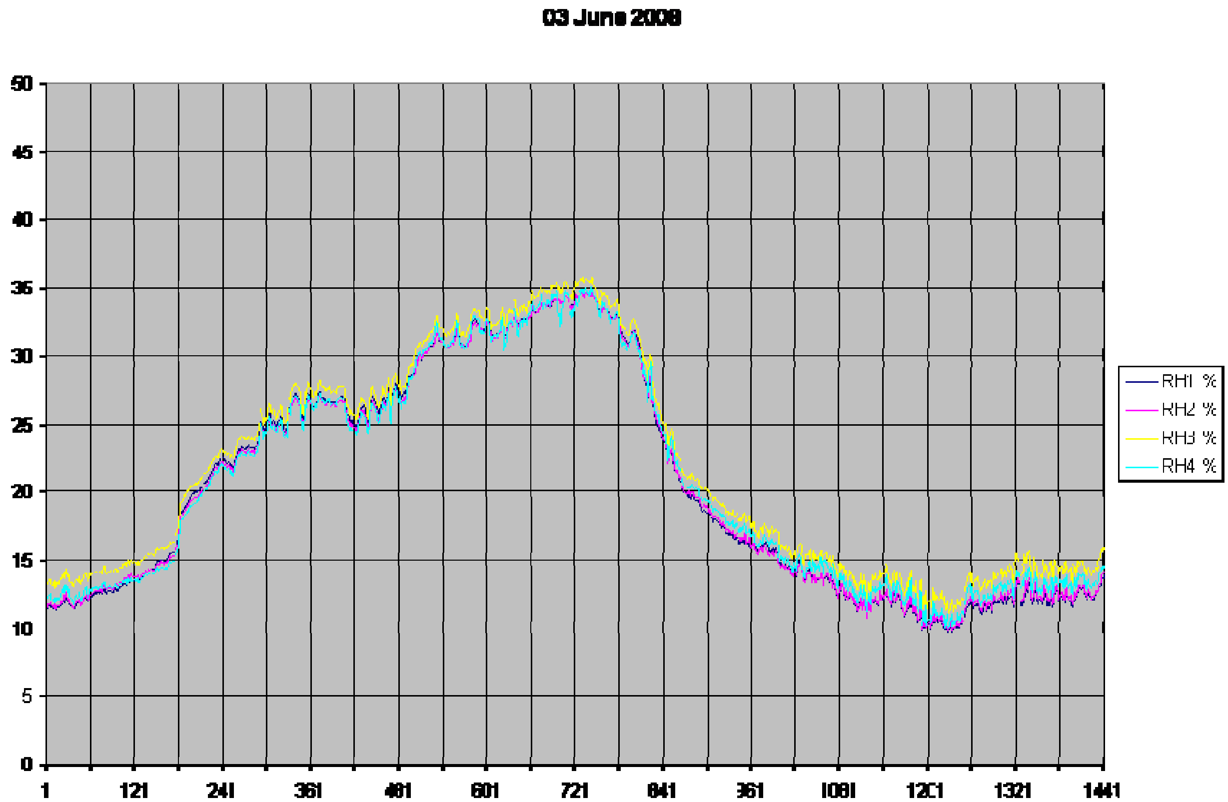

Figure 8. Plot showing relative humidity profile for the same time period as Figure 7.

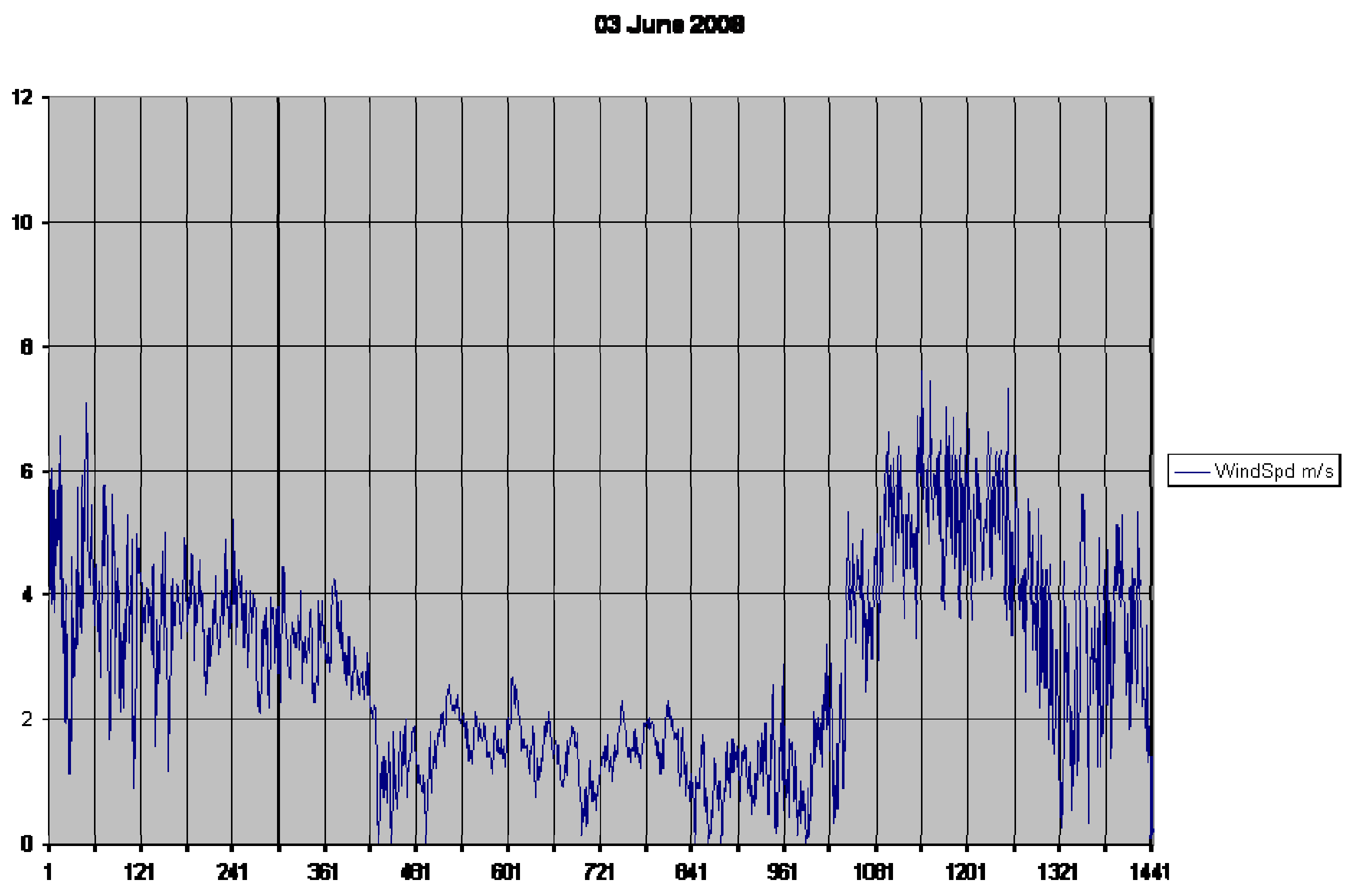

Figure 9. Plot showing relative wind speed (ms^{-1}) for the same time period as Figure 7.

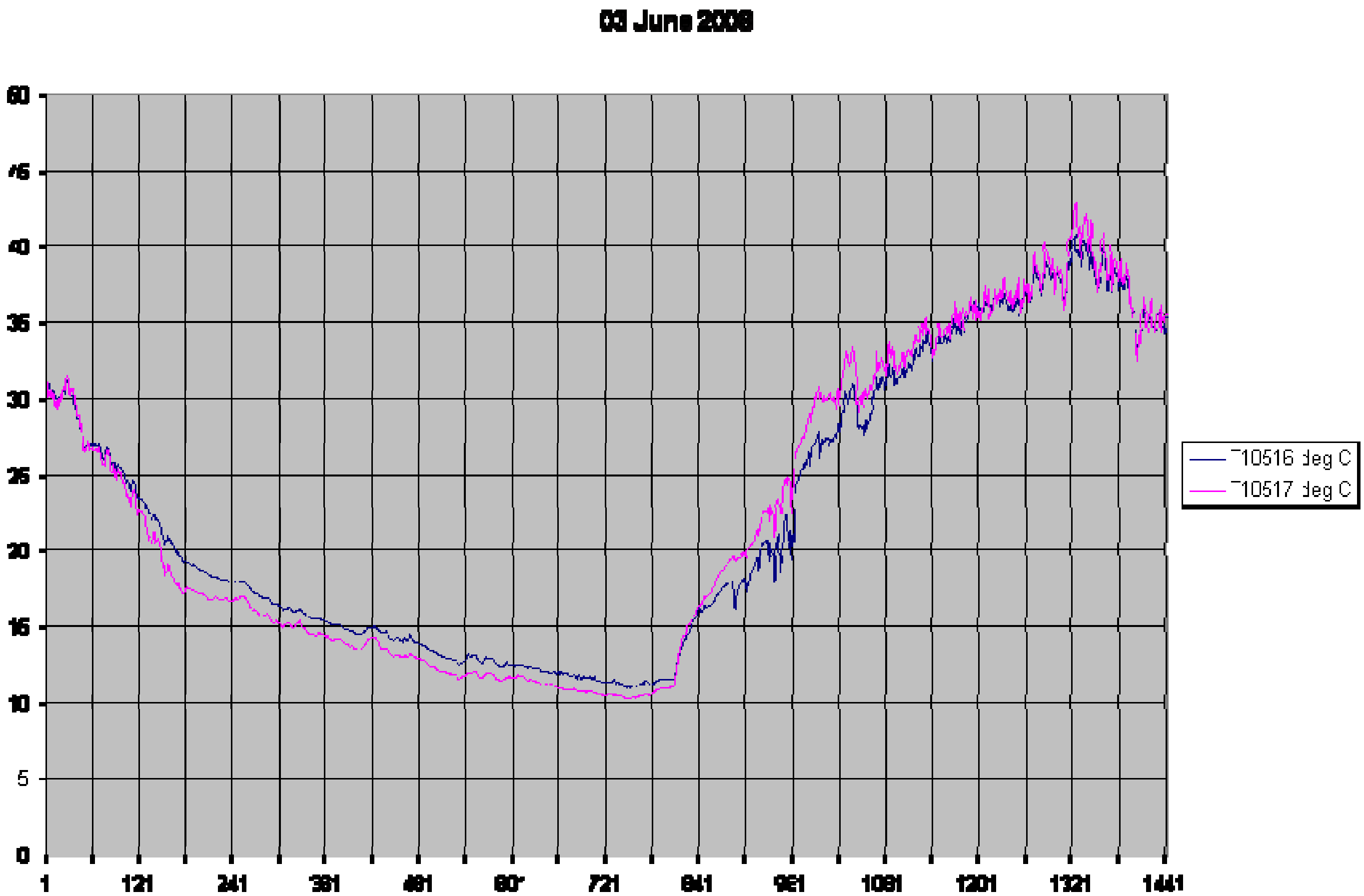

Figure 10. Plot showing relative wind speed (ms^{-1}) for the same time period as Figure 7.

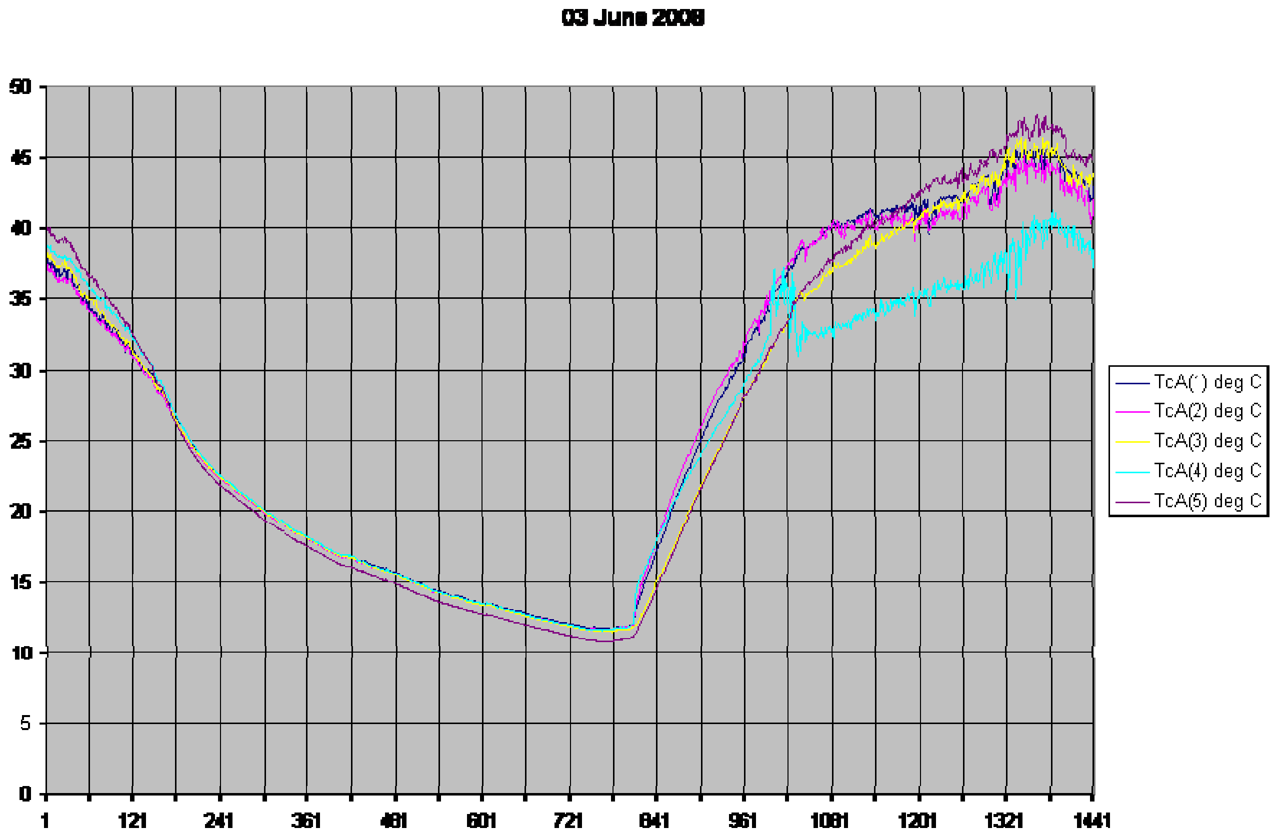

Figure 11. Plot showing temperatures and various locations on the exposed 120 mm shell (◦C) for the same time period as Figure 7.

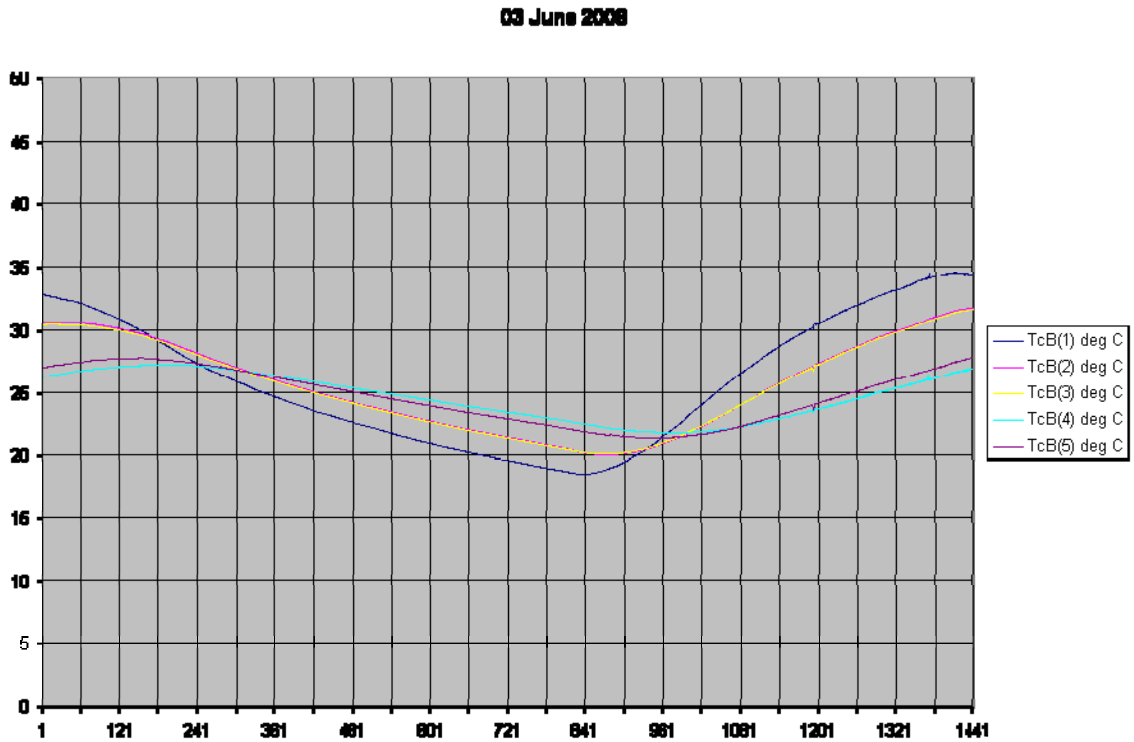

Figure 12 Plot showing relative soil temperatures (◦C) for the same time period as Figure 7. Sensor 1 was located at 5 cm below the surface, sensors 2 and 3 were located 10 cm below the surface and sensors 4 and 5 were located 20 cm below the surface

B. Aircraft measurements

The authors have the DVDs with all the available UNCLASSIFED movies in their possession. At the present time, it is not possible to display still images of these movies; the authors are working on converting the DVD movies to digital formats that will allow easy manipulation and still image creation.

A surprising result from the initial views of these movies was that the exposed "IED" (120 mm shell) was almost impossible to detect with the aircraft IR sensors because its surface was almost the same temperature of the surrounding surface. It was actually easier to detect the buried IED with the IR sensors because the associated soil disturbance caused more thermal contrast than the exposed IED.

In addition to the two aircraft described in section III, a remotely-piloted Predator aircraft also obtained movie images of the targets just before and for several days after the formal end of the measurement period. The authors do not yet have possession of these movies, but this is planned. Although the associated environmental measurements will not be available for most of the Predator flight periods, these movies were based on different sensors and will provide an interesting and useful comparison with the F-16 and AV-8B aircraft movies.

C. Other Data Sources

A similar data collection effort was performed by NRL personnel. These data are not shown here, but the authors have them in their possession for analysis. In addition, local standard meteorological data such as satellite images, upper-air soundings and other atmospheric data will be used in the analysis.

D. Pilot Interviews

Formal briefs and informal discussions with the pilots proved to be highly informative and enlightening. LtCol. Brian Patterson, USAF, the F-16 pilot and a test pilot instructor, has considerable experience flying in Iraq and other locations and has been actively involved in operational IED detection from aircraft. He noted that while it is difficult to find IEDs in unfamiliar terrain in Iraq, he has been able to detect them along roads that he was familiar with, usually by detecting the disturbed soil. He performed many missions to search for IEDs along roads where US ground forces would be traveling in convoys. He was well aware that certain times of the day and approach angles are better for IED detection, but that in most cases his search mission times were dictated by operational factors (i.e. just before the ground commanders decide to move) rather than during ideal detection times. He emphasized the importance and usefulness of our research and TAWS improvements for such missions.

V. CONCLUSIONS

The authors believe that the BANGEX 5 measurement program was highly successful. All the planned measurements were successfully performed, including several hours of movies from the aircraft. There is more than enough data for Capt. Bieger's thesis research and research by the other authors and colleaguess at NRL. We believe that analysis of these data as will lead to TAWS model improvements and will be a significant help to helping our forces defeat IEDs in Iraq and Afghanistan in the near future (1-2 years).

The authors' quick analysis of the initial results reveals possible positive and negative outcomes with regards to our goal of improving our forces ability to detect IEDs. On the negative side, it was disappointing that it was difficult to detect the actual simulated IEDs in many cases. We had hoped to be able to use thermal signatures to distinguish disguised and buried IEDs from empty coverings and disturbed soil without IEDs. Our initial looks at the movies did not reveal obvious thermal signature differences between the IED locations vs. locations with no IED (i.e. burlap or plastic bags or disturbed soil with or without IEDs). However this conclusion was based on very few looks at the aircraft movies. The authors still believe that it is possible to detect direct IED thermal signatures at certain times of the day and this will be a focus of the future research using these data.

On the positive side, we found that disturbed soil was easily detected. Therefore this provides a method to locate possible IED locations. The locations could then be examined further with low flyers or ground forces. Indeed this method is already in use in Iraq and Afghanistan and detection model improvements will aid these efforts.

While it is difficult for high flying aircraft sensors to locate IEDs in unfamiliar areas on a reliable basis, it is possible (based on our measurement results and discussions with pilots who have flown operational missions) to detect roadside IEDs in locations the pilots are familiar with based on disturbances to the soil that are detectable from the high flying aircraft.

The results from future research will be made available to the JIEDDO program in the coming months through theses and reports by the authors.

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